MSFC-2045- ABSTRACT

2008 Huntsville Workshop abstract

Magnetic Reconfiguration in CMEs/Ejective Flares

Ron Moore, Alphonse Sterling, Steve Suess

We present (1) the standard concept for the large transient change in field configuration in the solar magnetic explosions that produce an ejective flare and become a coronal mass ejection (CME) and (2) an observational test of this picture of CME production. In linear span, the largest change in field configuration in these events is wrought by the CME in the outer corona and solar wind. In the outer corona, the CME is essentially a magnetic bubble that transiently pushes aside the previously radial surrounding field. The source magnetic field that explodes to become the CME is initially a closed arcade enveloping sheared and twisted sigmoid field that snakes along the polarity dividing line and forms the core of the arcade. The sigmoid field has a large store of pent-up free magnetic energy. This eventually causes the sigmoid to become unstable and to begin to erupt as a flux rope. The erupting flux rope becomes the core of the CME plasmoid. The flux rope and enveloping CME plasmoid are created and built up (given more magnetic flux) and unleashed to escape by reconnection of the legs of the erupting sigmoid and arcade. Simultaneously, this tether-cutting reconnection produces beneath the escaping plasmoid a growing coronal X-ray flare arcade rooted in two separating ribbons of chromospheric flare emission. As the unleashed CME plasmoid propels itself into the outer corona, it takes with it the top of the arcade envelope field that arches over it. The continuing reconnection finally recloses the "opened" stretched legs of the envelope, thus restoring the pre-eruption closed-arcade field configuration. This reconnection scenario for producing the CME plasmoid implies that the magnetic flux spanned by the full-grown flare arcade nearly equals the magnetic flux in the CME plasmoid in the outer corona. We have found that a wide range of exploding source regions produce CMEs that pass this test for production by tether-cutting reconnection (Moore, Sterling, & Suess 2007, ApJ, 668, 1221).

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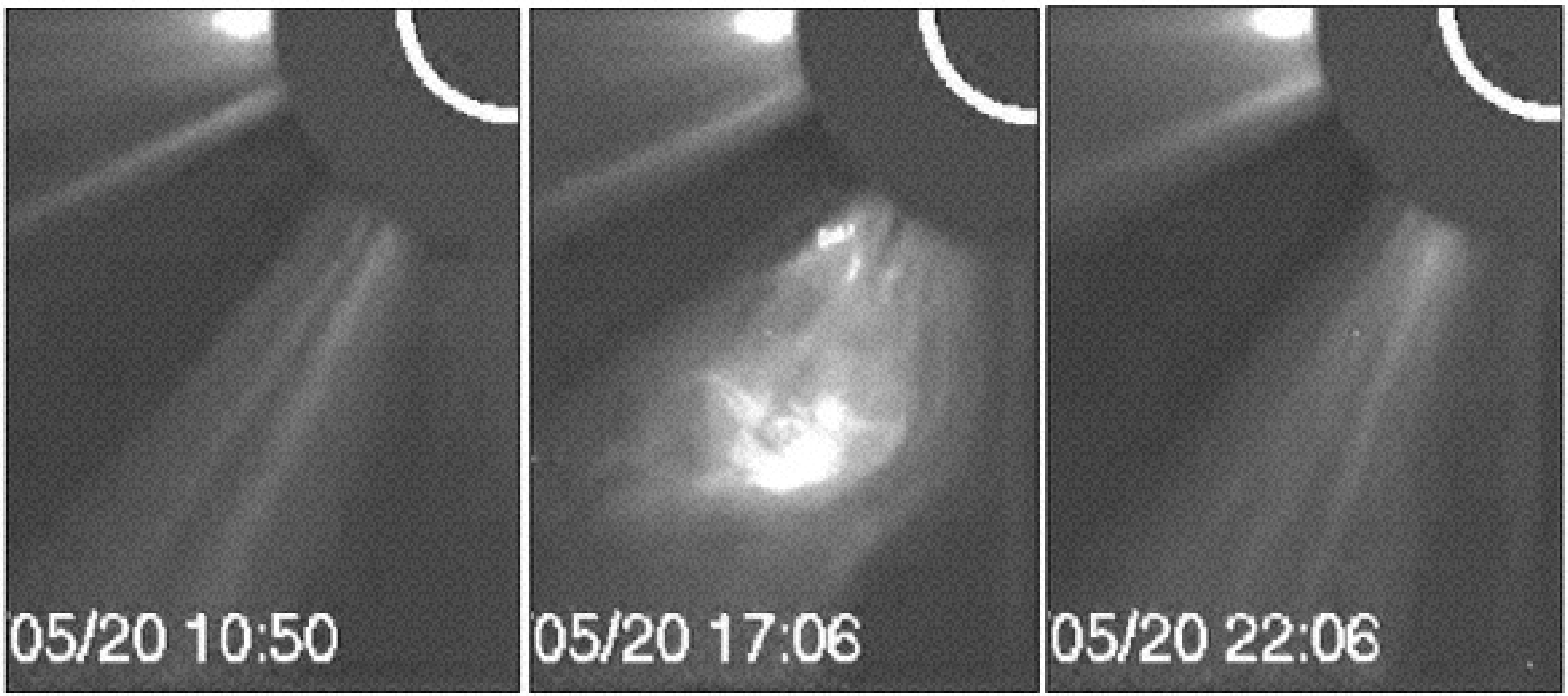
NASA/MSFC/National Space Science and Technology Center

Typical CME

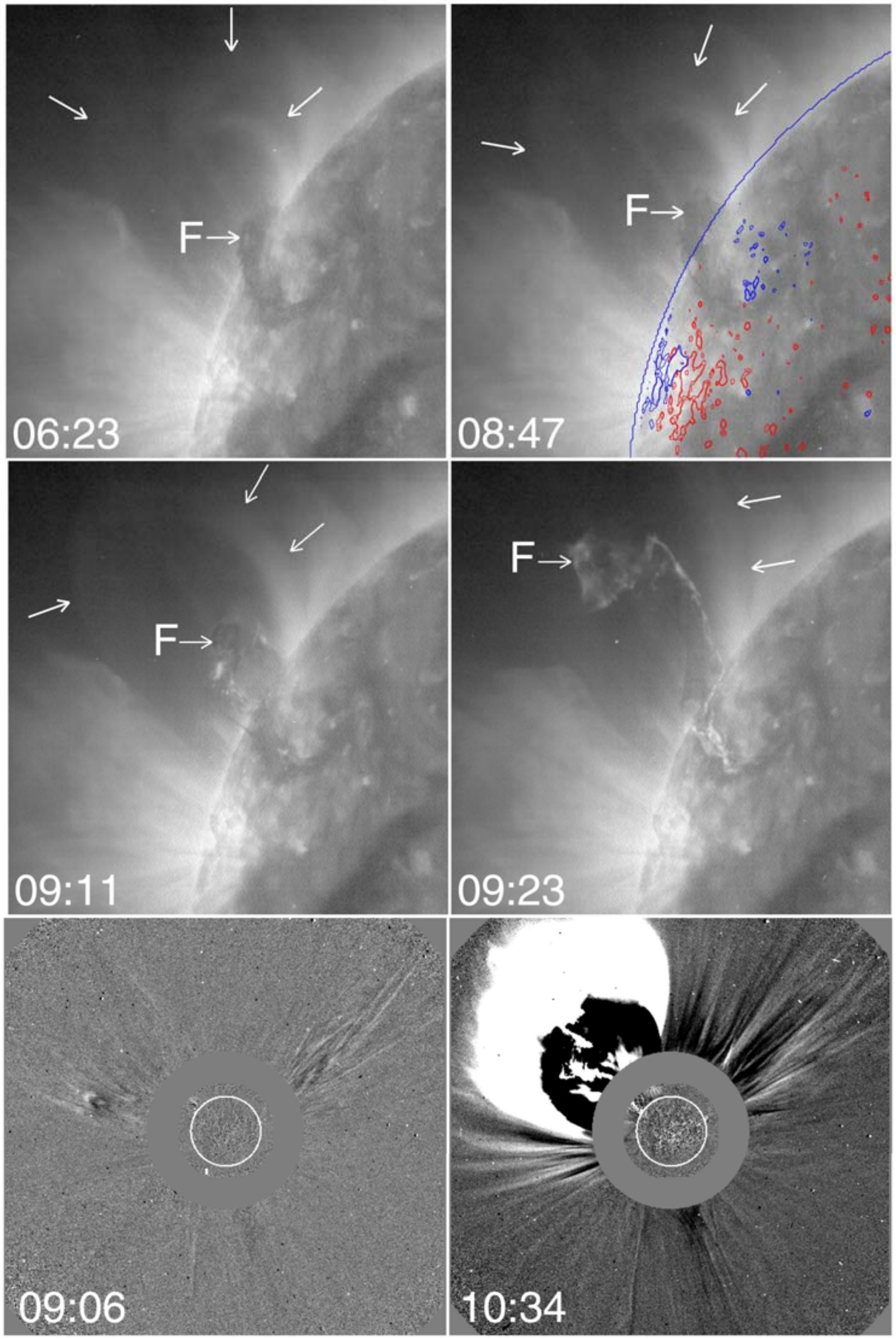
Observed by LASCO/C2 Coronagraph on SOHO



2002 May 20

Typical CME Source Explosion

Filament-traced sheared core field and enveloping arcade erupt, expand, and escape to form the CME

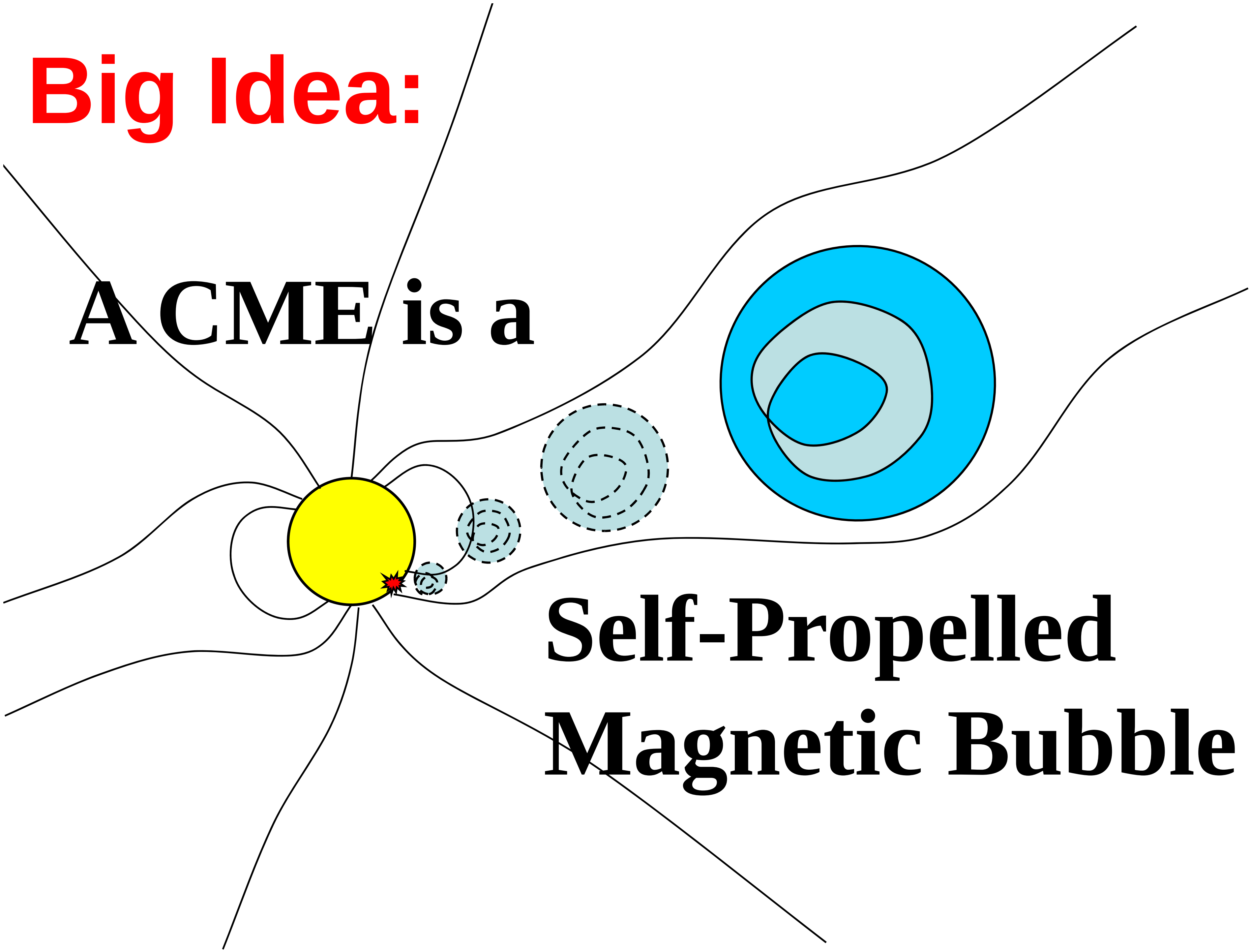


CME/Ejective Flare of 2002 Jan 4

Big Idea:

A CME is a

Self-Propelled Magnetic Bubble



Main Points

- The standard scenario for CME production is basically the right physical picture.
- A CME is a magnetically inflated (low-beta) “plasmoid with legs.”
- Tether-cutting reconnection is only one way to <u>trigger</u> a CME explosion.
- Tether-cutting reconnection does <u>most</u> of the building and unleashing of the CME plasmoid.
- The CME propels itself by pushing on the surrounding coronal magnetic field.

Outline

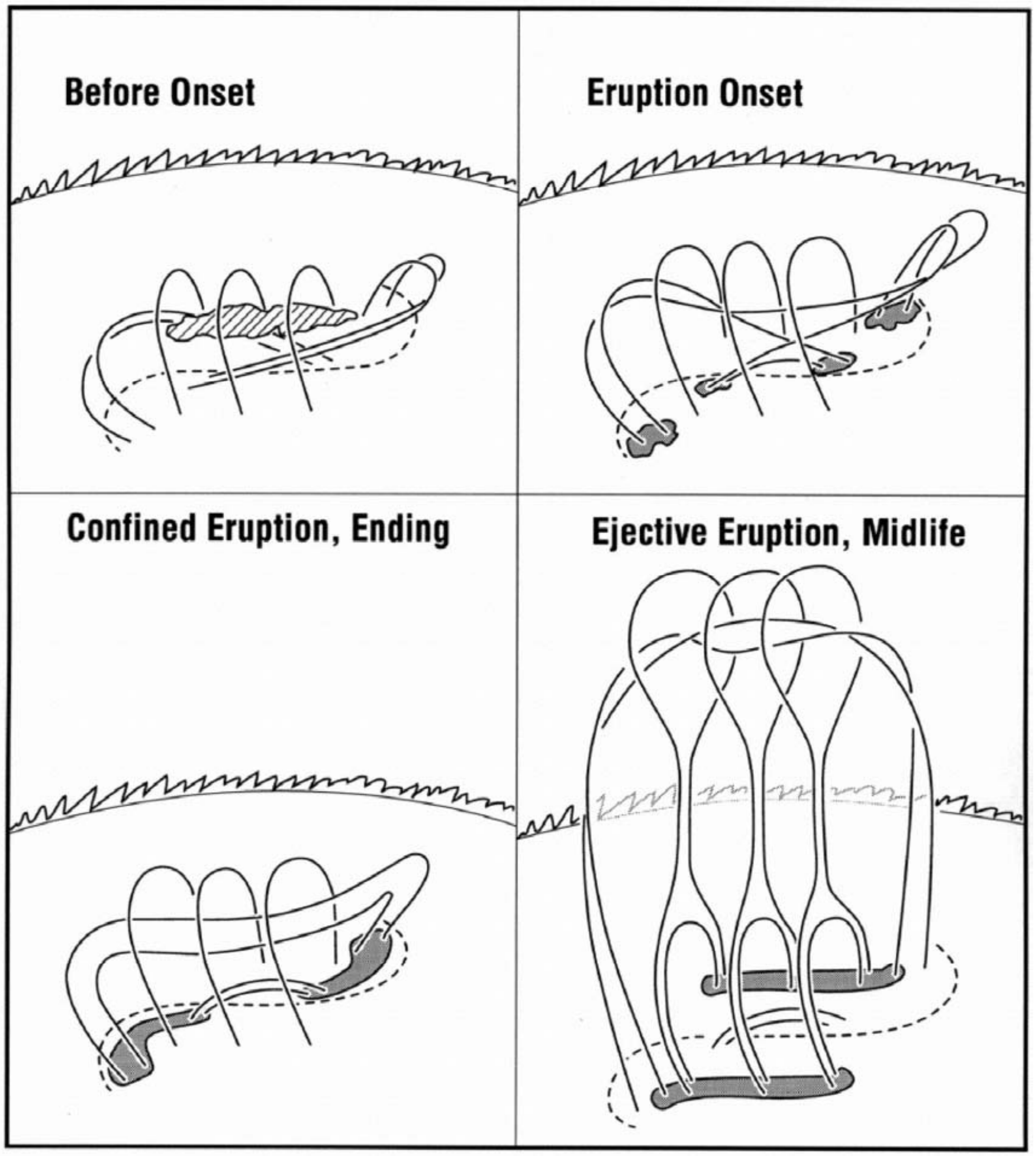
I. Introduction

II. Standard Scenario for CME Production

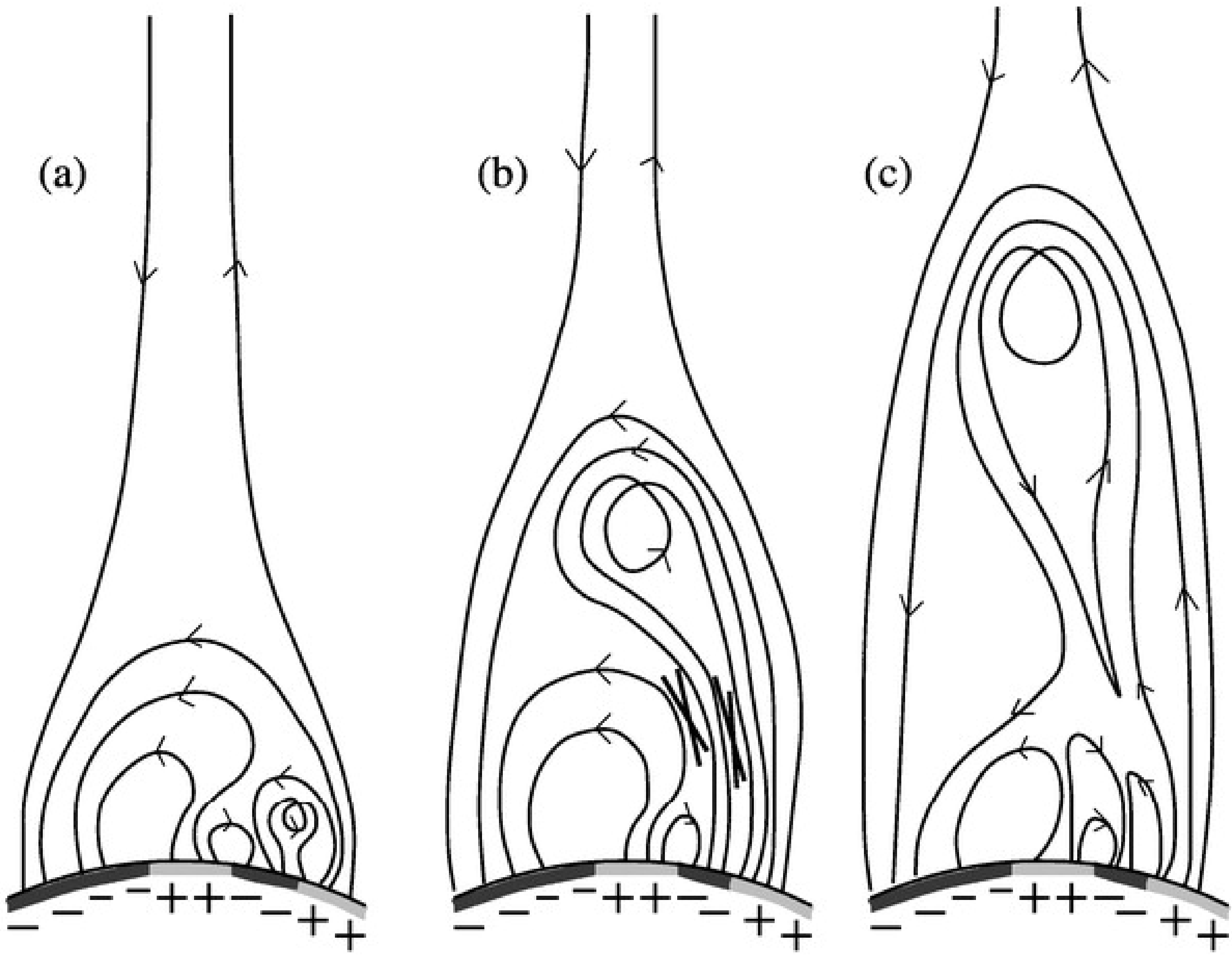
III. Observational Test

IV. Conclusion

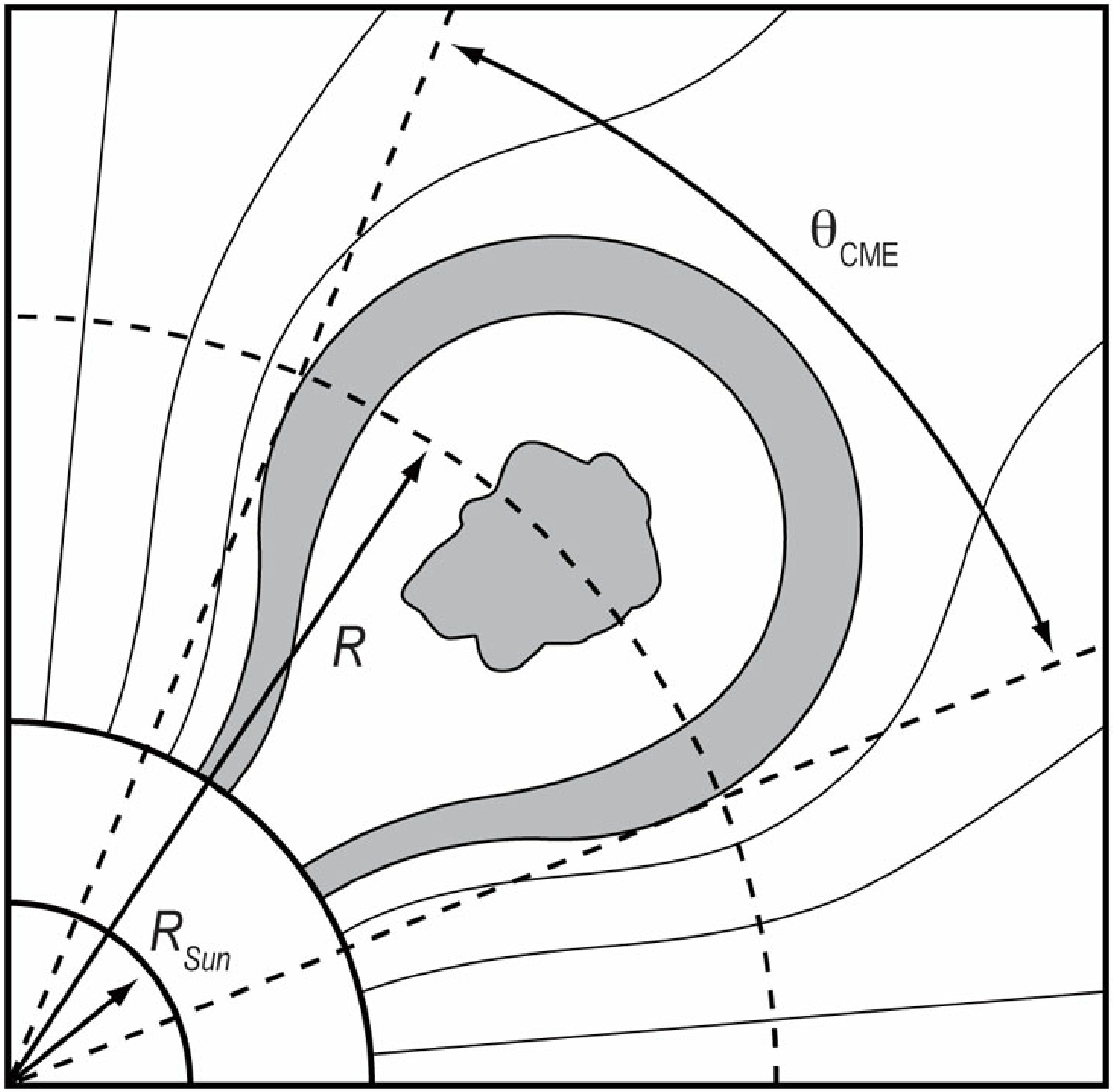
Birth and Release of the CME Plasmoid



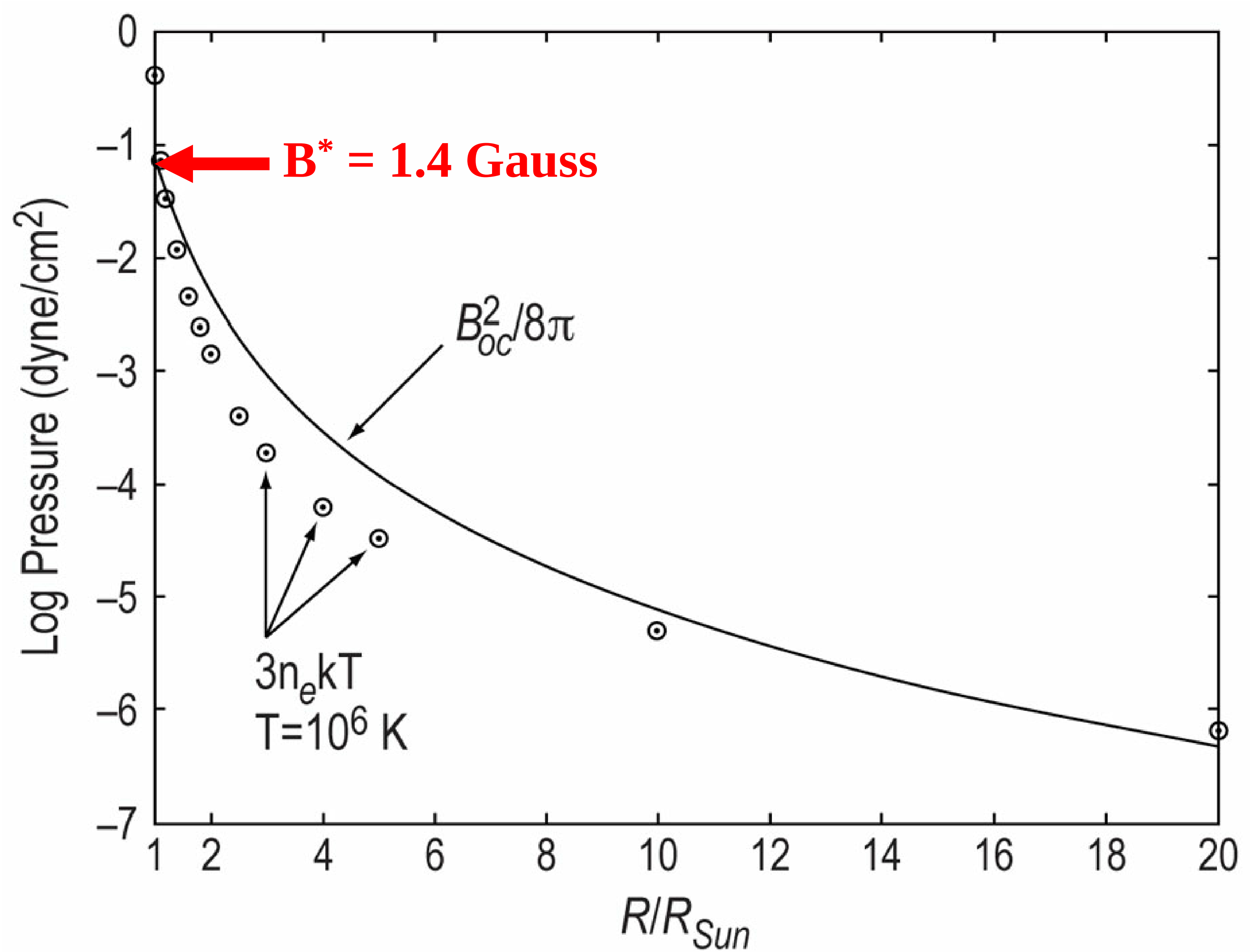
Escape Path Determined by Surrounding Field



Resulting CME in Outer Corona



Lateral Pressure in Outer Corona



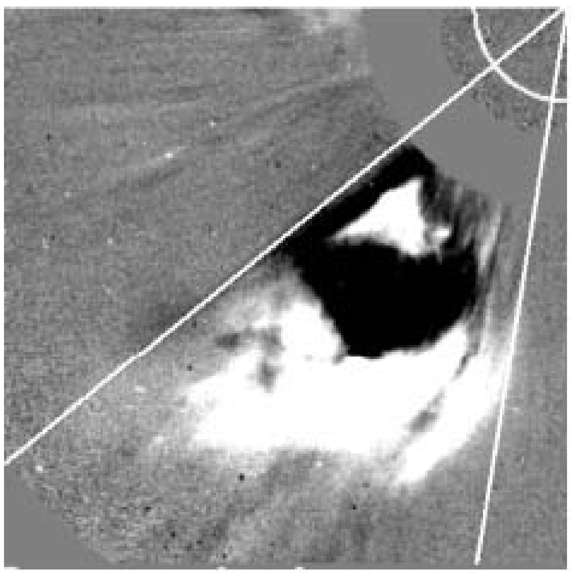
Testable Prediction of the Standard Scenario for CME Production:

$$B_{Flare} \approx 1.4(\theta_{CME}/\theta_{Flare})^2 \text{ Gauss}$$

Our 3 Test CMEs

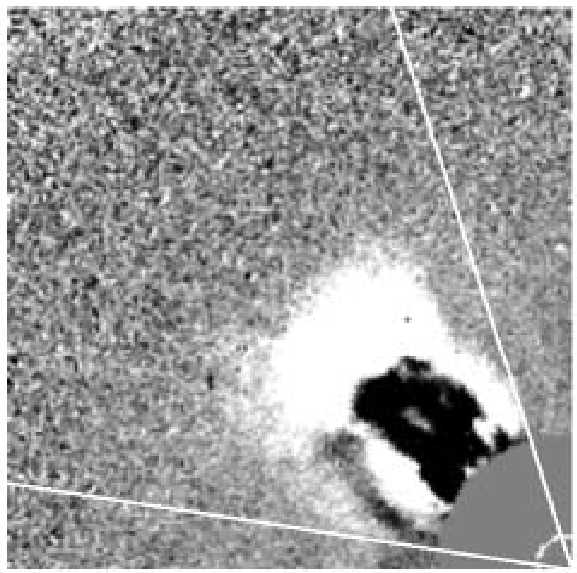
at Final Width in Outer Corona

2002 May 20



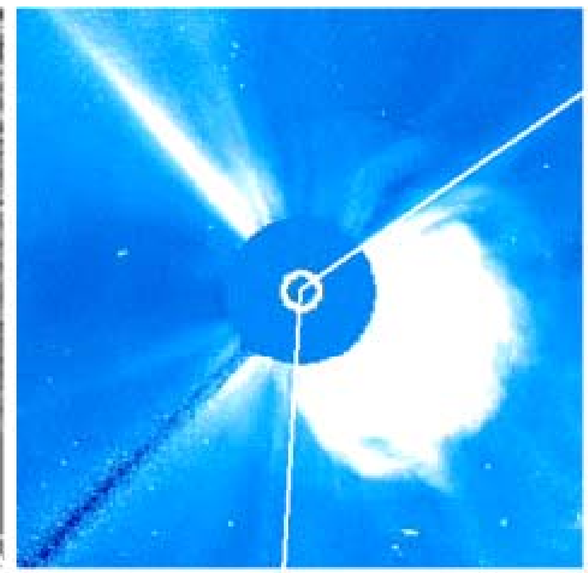
C2 Difference Image

1999 Feb 9



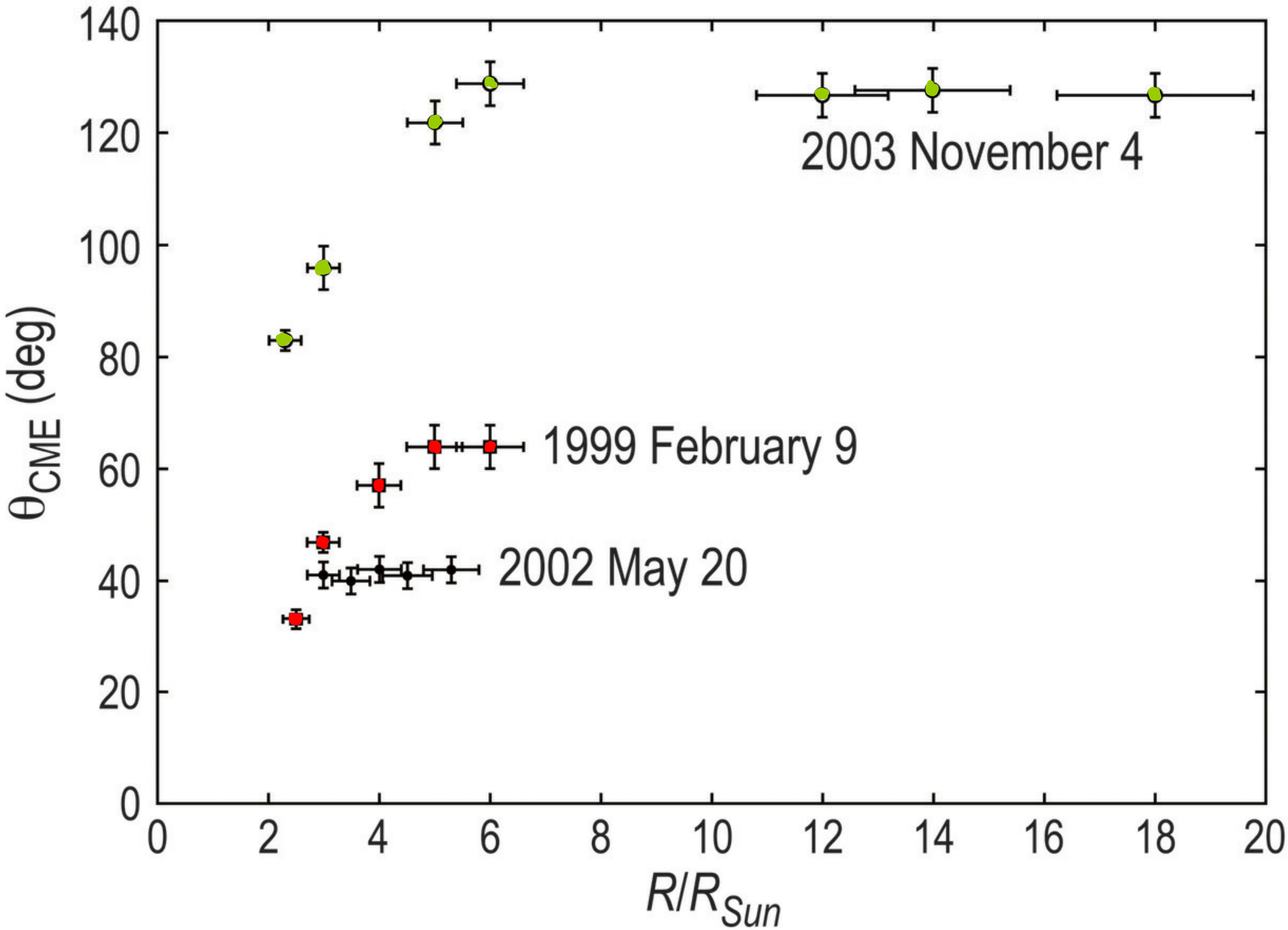
C3 Difference Image

2003 Nov 4

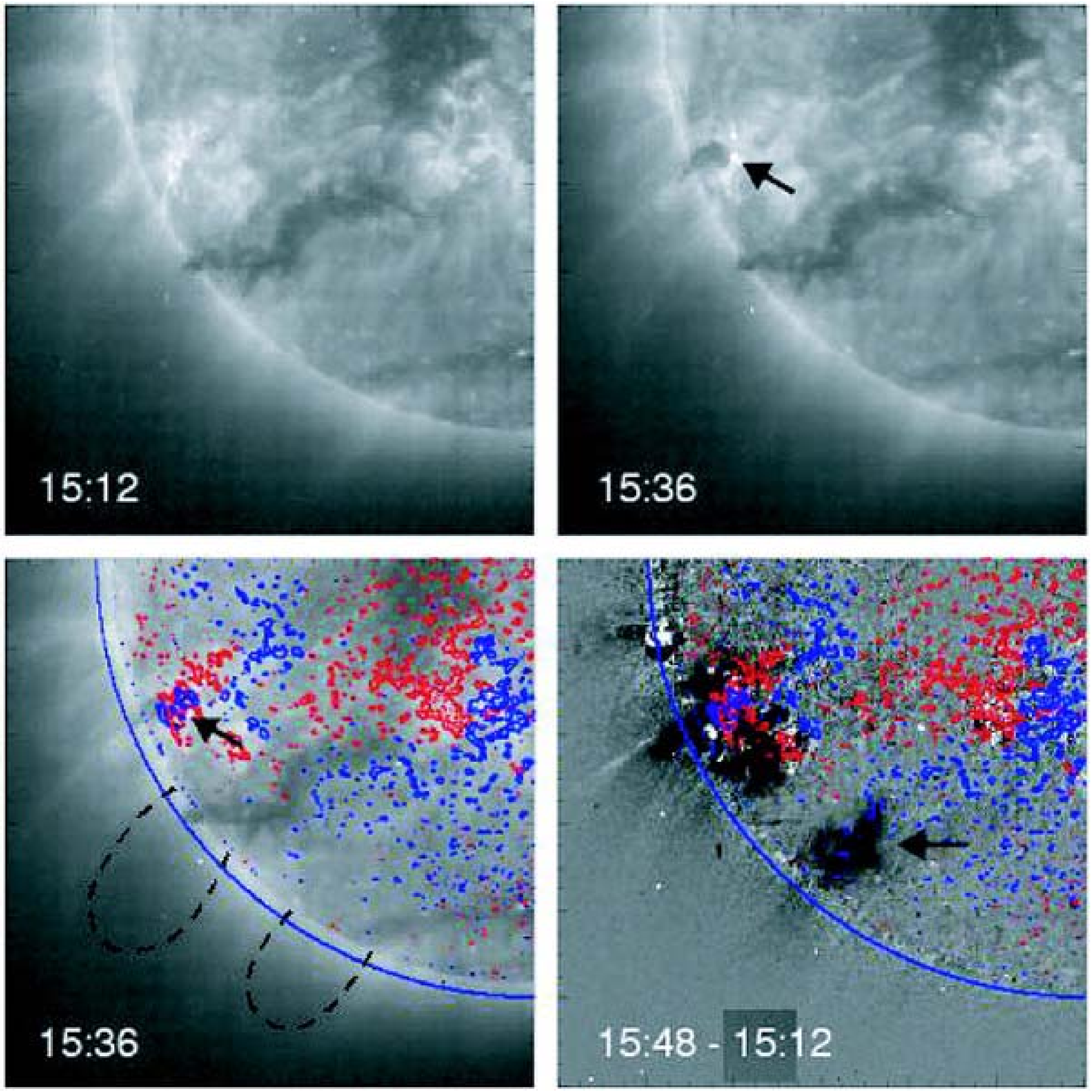


C3 Direct Image

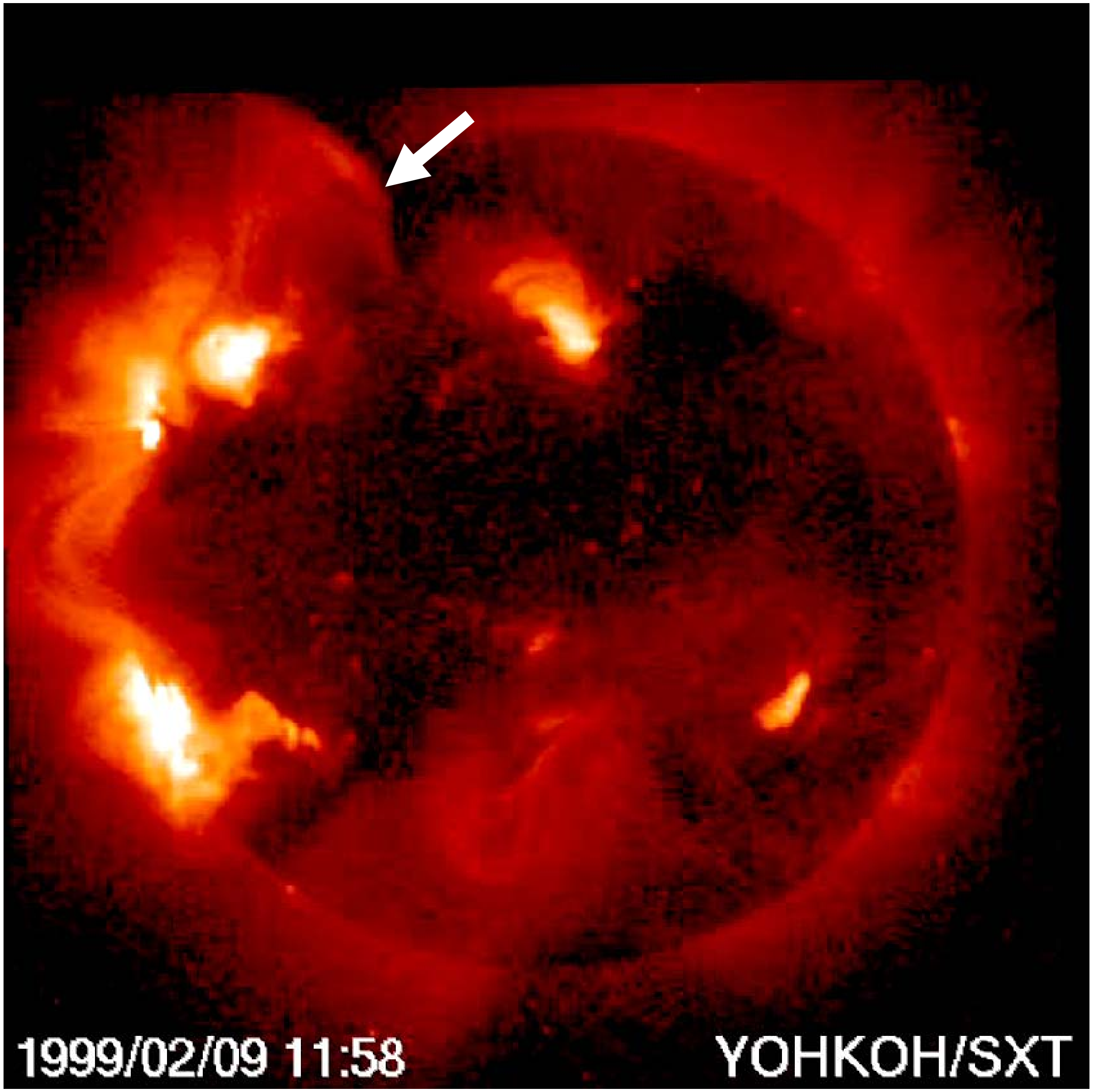
Measured Angular Widths of each CME



Source of the CME of 2002 May 20

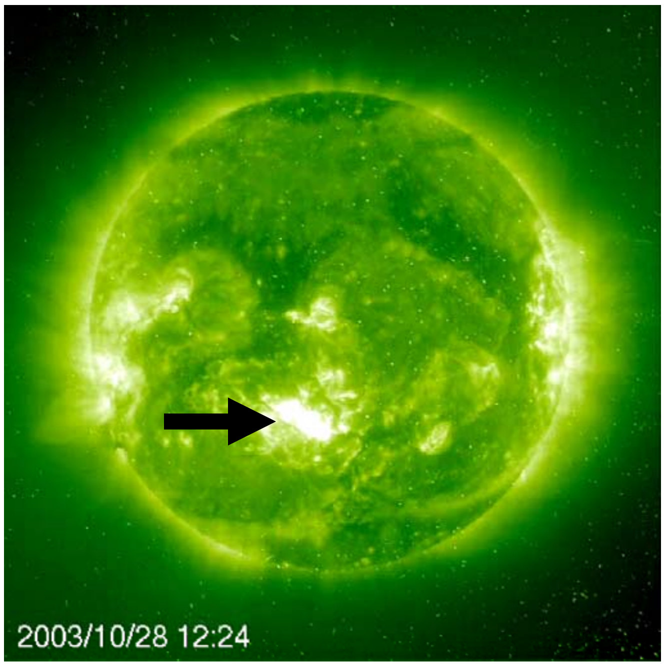


Source of the CME of 1999 Feb 9



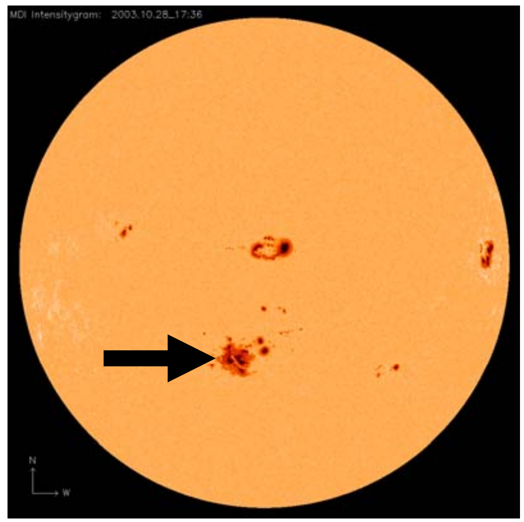
Source of the CME of 2003 Nov 4

Oct 28 X17 Flare Arcade



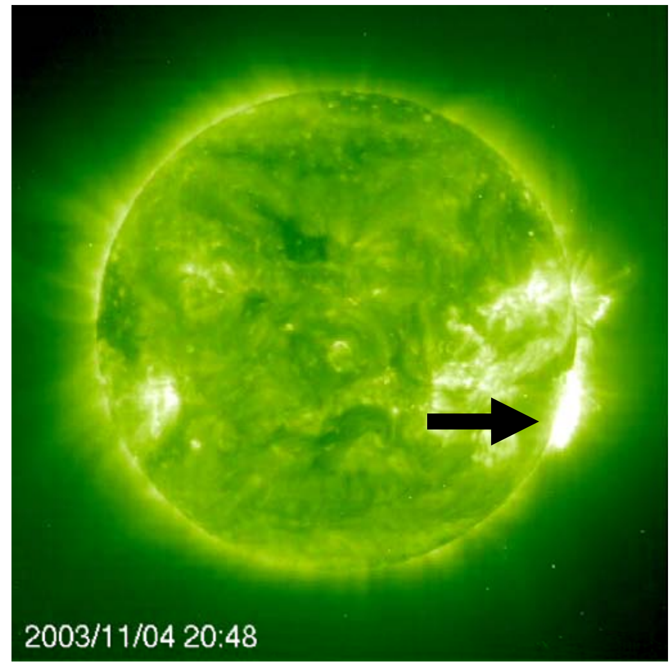
EIT 195 Å Corona

Giant δ Sunspot Centered Under Flare Arcade



MDI Photosphere

Nov 4 X20 Flare Arcade



EIT 195 Å Corona

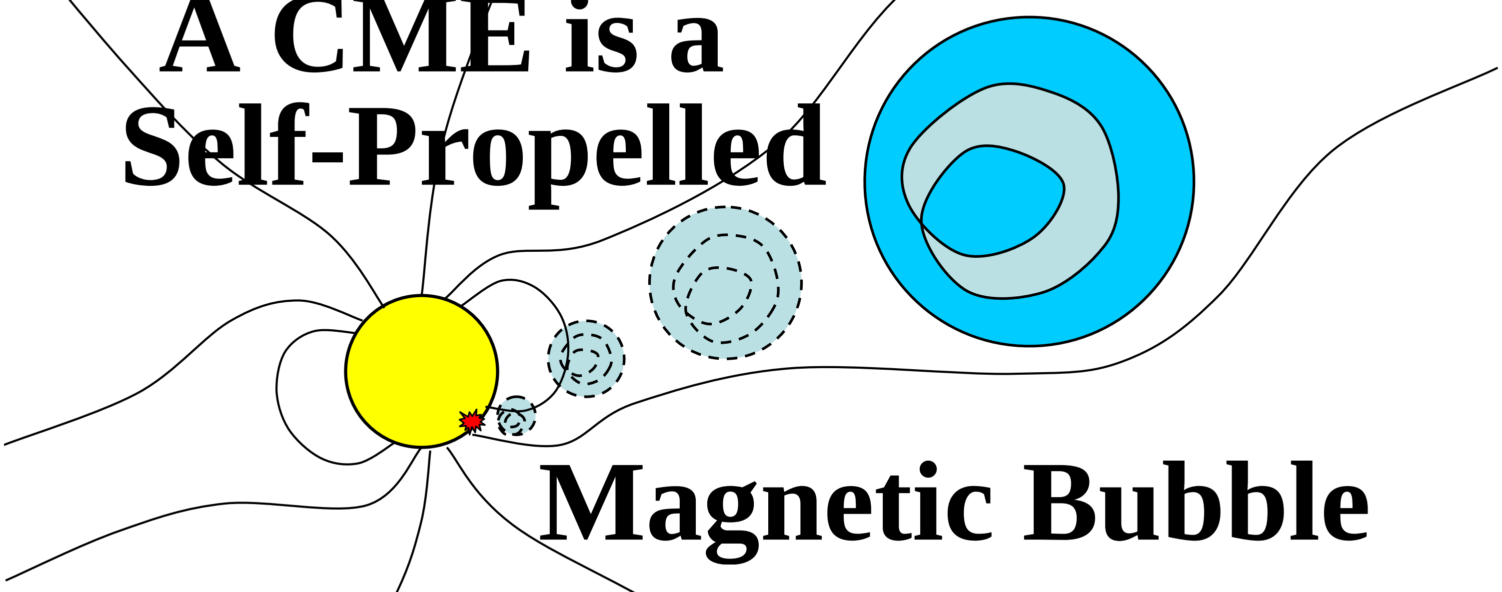
Test Results

CME (date)	Source Region	θ_{CME} (deg)	θ_{Flare} (deg)	Predicted* B_{Flare} (Gauss)	Predicted B_{Flare} Fits Source Region? (Yes/No)
2002 May 20	Centered on small δ spot	41	2.2	≈ 490	Yes
1999 Feb 9	Quiet region filament arcade	64	27	≈ 8	Yes
2003 Nov 4	Centered on giant δ spot	128	8.7	≈ 300	Yes

* Predicted $B_{Flare} \approx 1.4(\theta_{CME}/\theta_{Flare})^2$ Gauss

CONCLUSION:

A CME is a Self-Propelled Magnetic Bubble



- Low-beta plasmoid
- Built and unleashed by tether-cutting reconnection
- Propelled by own magnetic field pushing on surrounding field